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Title:

A CERAMIC CORE, A DISPOSABLE PATTERN, A METHOD OF MAKING A DISPOSABLE PATTERN, A METHOD OF MAKING A CERAMIC SHELL MOULD AND A METHOD OF CASTING ;

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Equivalents: ;

ABSTRACT:

A disposable pattern (28) (e.g. wax) is moulded around at least one ceramic core (20) and the ceramic core (20) comprises at least one aperture extending through the ceramic core (20). A support member (22) is arranged in the at least one aperture such that each end of the support member (22) projects from the ceramic core (20) by a predetermined distance. The disposable pattern 28 is coated with ceramic material to form a shell mould 32. The resultant assembly is heated to melt the pattern 28 whereby support member (22) positions the ceramic core (20) in the ceramic shell mould (32). Mould 32 is fired to remove remaining traces of pattern 28 and to cure the mould 32. Molten metal (e.g. alloy, superalloy, intermetallic) is then cast using mould 32 to form a turbine blade (10), figure 1 (not shown). The support member (22) does not project into the ceramic shell mould (32) and therefore does not produce recrystallisation in the castings. The support member (22) does not project from the castings and hence does not need dressing to remove the projecting portion of the support member (22).

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(54) Abstract Title

A ceramic core, a disposable pattern, a method of making a disposable pattern, a method of making a ceramic shell mould and a method of casting

(57) A disposable pattern (28) (e.g. wax) is moulded around at least one ceramic core (20) and the ceramic core (20) comprises at least one aperture extending through the ceramic core (20). A support member (22) is arranged in the at least one aperture such that each end of the support member (22) projects from the ceramic core (20) by a predetermined distance. The disposable pattern 28 is coated with ceramic material to form a shell mould 32. The resultant assembly is heated to melt the pattern 28 whereby support member (22) positions the ceramic core (20) in the ceramic shell mould (32). Mould 32 is fired to remove remaining traces of pattern 28 and to cure the mould 32. Molten metal (e.g. alloy, superalloy, intermetallic) is then cast using mould 32 to form a turbine blade (10), figure 1 (not shown). The support member (22) does not project into the ceramic shell mould (32) and therefore does not produce recrystallisation in the castings. The support member (22) does not project from the castings and hence does not need dressing to remove the projecting portion of the support member (22).

Fig.5.

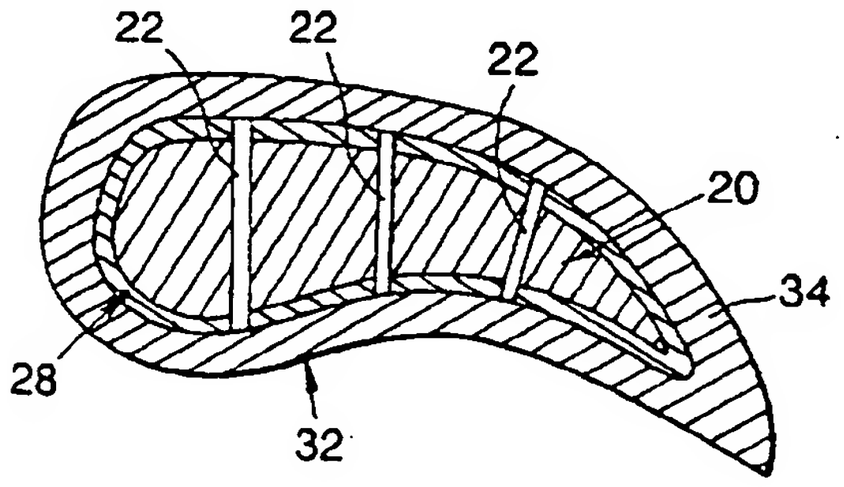
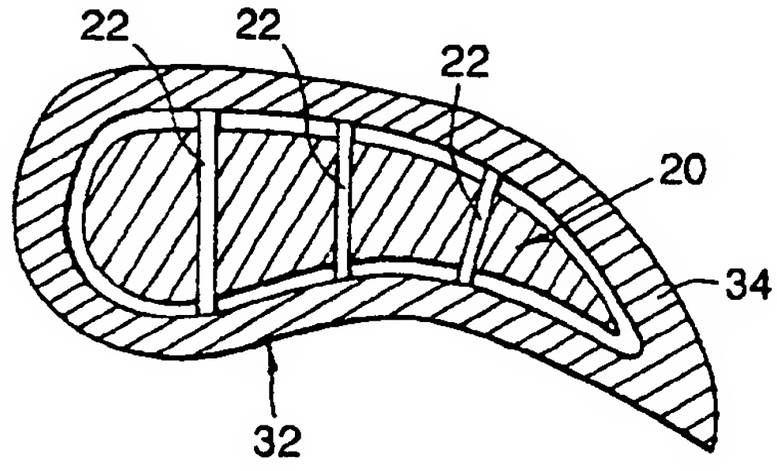


Fig.6.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig.1.

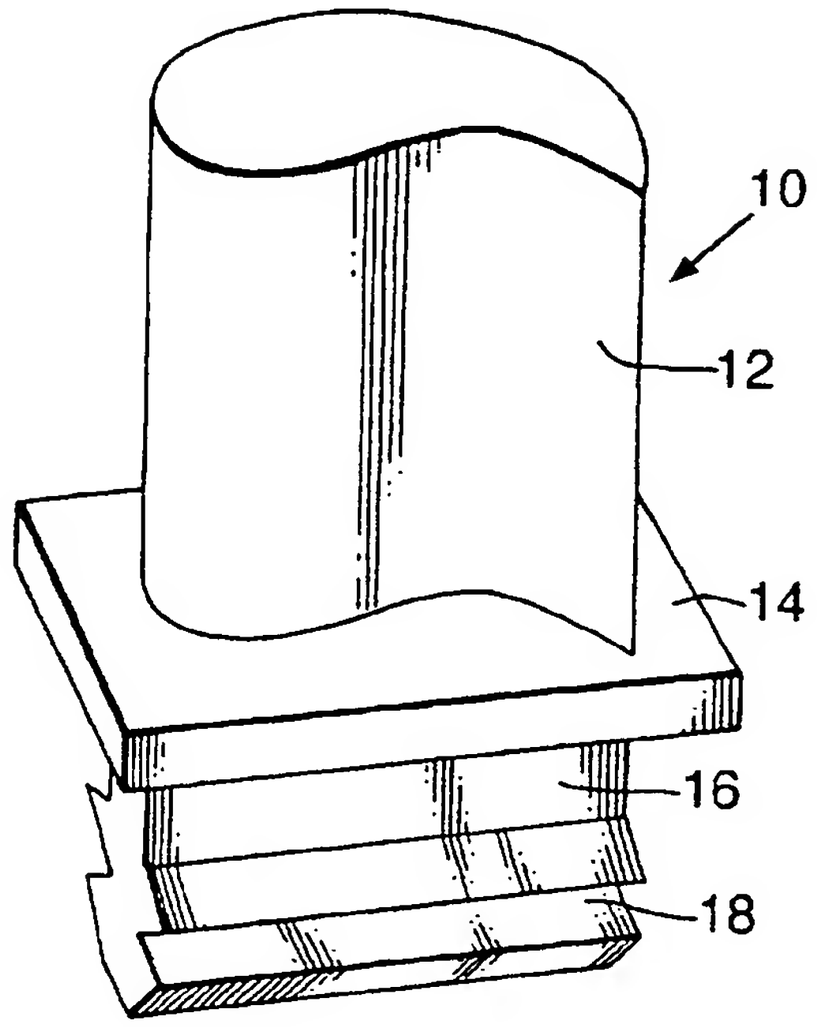


Fig.2.

Fig.3.

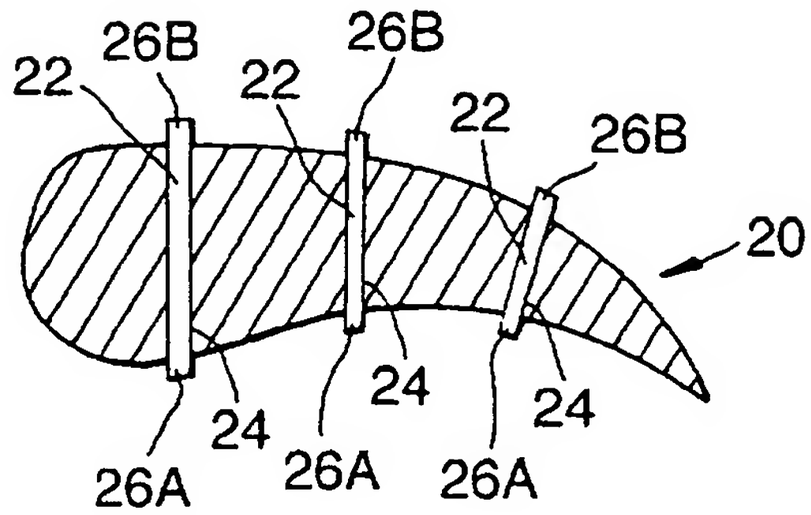


Fig.4.

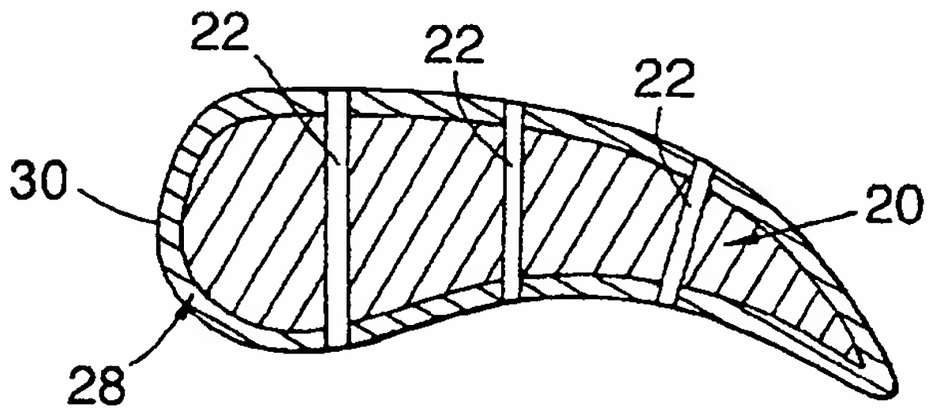


Fig.5.

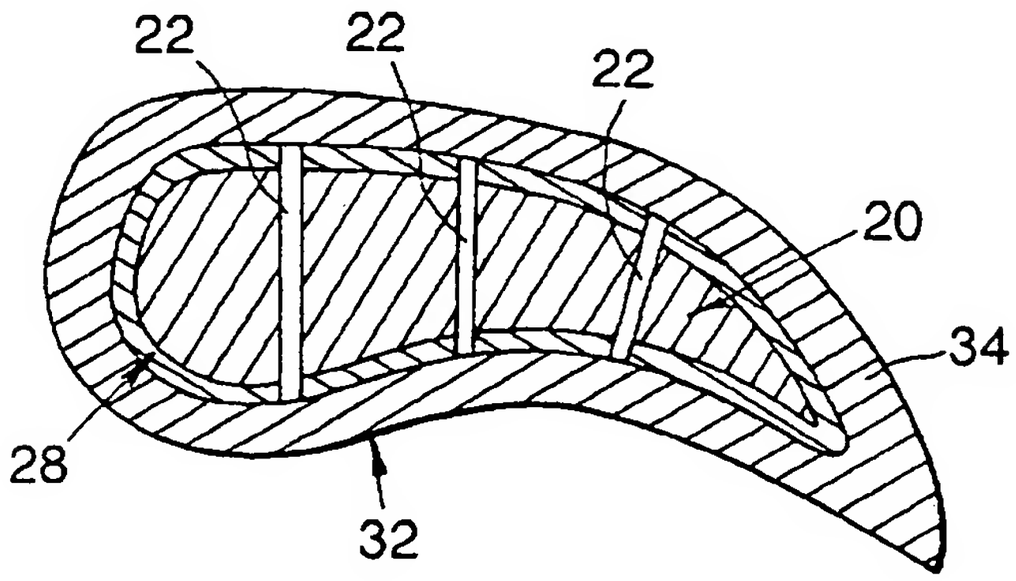


Fig.6.

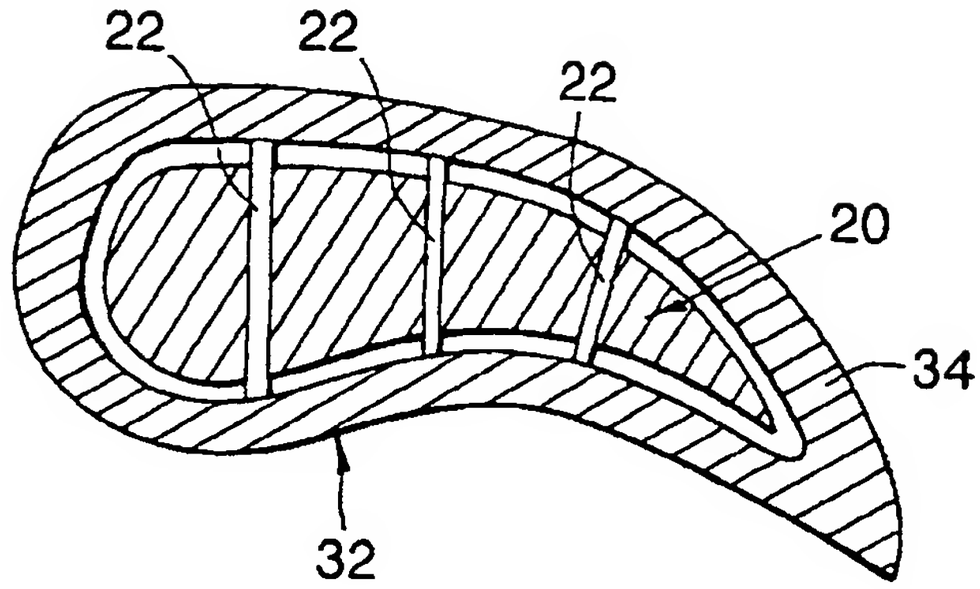


Fig.7.

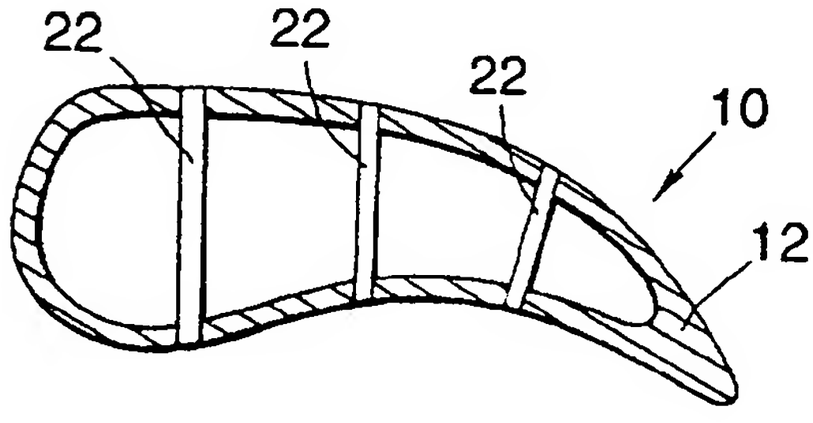
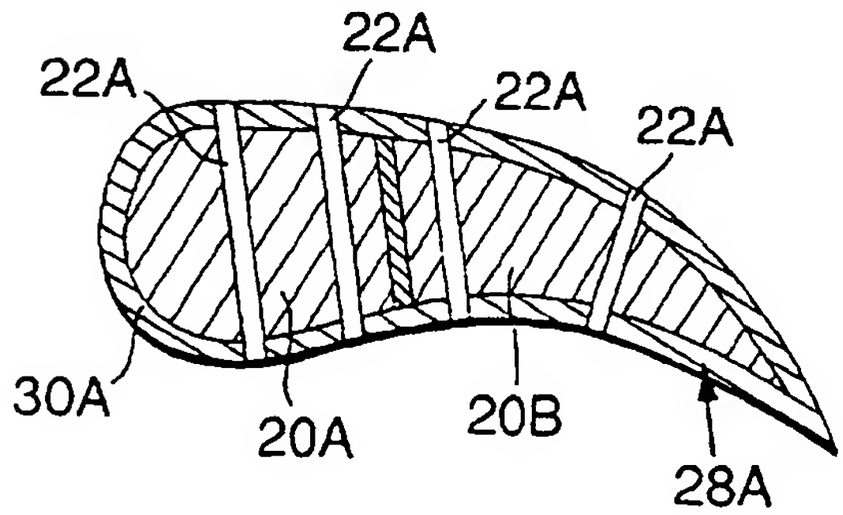


Fig.8.



A CERAMIC CORE, A DISPOSABLE PATTERN, A METHOD OF MAKING A DISPOSABLE PATTERN, A METHOD OF MAKING A CERAMIC SHELL MOULD AND A METHOD OF CASTING

The present invention relates generally to a ceramic core, particularly a ceramic core for investment casting, a disposable pattern, particularly for investment casting, a method of making a disposable pattern, particularly a wax pattern for investment casting, a method of making a ceramic shell mould, particularly investment casting ceramic shell moulds and to a method of casting, particularly investment casting.

In investment casting, or lost wax casting process, a wax pattern of a component, or article, is produced. The wax pattern is a replica of the component, or article, to be produced. Usually a number of wax patterns are assembled together on a runner to form a wax pattern assembly. Usually the wax runner is formed on a support member. The wax pattern assembly is immersed in a liquid ceramic slurry which quickly gels after draining, strengthening refractory granules are sprinkled over the ceramic slurry covered wax pattern assembly and the refractory granules bond to the slurry coating to produce a ceramic layer on the wax pattern assembly. This process is repeated several times to produce many ceramic layers which form the ceramic shell mould. The ceramic shell mould is dried and then heated so as to melt the wax pattern assembly such that the may run out of the ceramic shell mould to define an internal cavity identical in shape to the wax pattern assembly. The ceramic material is then fired to complete the ceramic shell mould. A suitable molten material, for example a metal, alloy, superalloy or intermetallic may then be cast in the ceramic shell mould.

It is frequently necessary to cast hollow components, or hollow articles, for example turbine blades, or turbine vanes, in which one or more passages are provided for the

flow of cooling fluid in operation of the turbine blade or turbine vane.

The investment casting process is then modified to provide one or more ceramic cores, which define the interior of the hollow component, or hollow article. The wax patterns are produced by injecting wax into a pattern die and one or more ceramic cores are located in the pattern die at the appropriate positions to define the interior of the hollow component, or hollow article.

A plurality of low melting point plastic chaplets are bonded onto the surface of the ceramic core to locate and space the ceramic core accurately in the pattern die while the wax is injected into the pattern die. A plurality of support pins, usually platinum, are then pushed through the wax so that one end of each support pin abuts the surface of the ceramic core and the other end of each support pin projects from the wax. The wax pattern assembly is coated with the ceramic slurry to produce the ceramic shell mould and the ceramic shell mould deposits around the projecting ends of the support pins. The wax is melted out of the ceramic shell mould and the support pins support the ceramic core and restrict its movement in the ceramic shell mould. The molten material is cast in the ceramic shell mould.

A problem with this process is that after the ceramic shell mould is removed from the cast hollow components, or hollow articles, the support pins project from the surface of the hollow components, or hollow articles. This makes it necessary to cut off the projecting ends of the support pins and dress the support pins so that they are flush with the surface of the hollow component, or hollow article. This is costly and time consuming. A further problem is that as the material cools in the ceramic shell mould it contracts. This puts a strain on the support pins and the cast hollow component, or cast hollow article, which causes recrystallisation of the material. If the hollow component, or hollow article, is a single crystal alloy, or a

directionally solidified alloy the recrystallisation is not acceptable and this leads to scrapping of the hollow component, or hollow article.

Accordingly the present invention seeks to provide a novel method of manufacturing a disposable pattern of a hollow component which overcomes the above mentioned problems.

Accordingly the present invention provides a method of manufacturing a disposable pattern of a hollow component comprising the steps of:

(a) forming a ceramic core,

(b) forming at least one aperture through the ceramic core,

(c) placing a support member in the at least one aperture such that each end of the support member projects from the ceramic core by a predetermined distance,

(d) placing the ceramic core and at least one support member in a die such that the ends of the support member locate the ceramic core in spaced relationship with the die to define the shape of the pattern of the hollow component,

(e) supplying molten disposable material into the space between the die and the ceramic core,

(f) allowing the disposable material to solidify to form a disposable pattern and

(g) removing the disposable pattern and ceramic core from the die.

Preferably step (b) comprises forming a plurality of apertures through the ceramic core and step (c) comprises placing a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

Preferably step (e) comprises supplying wax into the space between the die and the ceramic core.

Preferably the support member comprises platinum.

The present invention also provides a method of manufacturing a ceramic shell mould comprising the steps of:

(a) forming a ceramic core,

(b) forming at least one recess in the ceramic core,

(c) placing a support member in the recess such that at least one end of the support member projects from the ceramic core by a predetermined distance,

(d) placing the ceramic core and at least one support member in a die such that the ends of the support member locate the ceramic core in spaced relationship with the die to define the shape of the pattern of the hollow component,

(e) supplying molten disposable material into the space between the die and the ceramic core,

(f) allowing the disposable material to solidify to form a disposable pattern and

(g) removing the disposable pattern and ceramic core from the die,

(h) coating the disposable pattern with ceramic material to form a mould,

(i) heating the mould, disposable pattern and ceramic core to remove the disposable pattern from the mould, and

(j) firing the mould to complete the ceramic shell mould.

Preferably step (b) comprises forming at least on aperture through the ceramic core and step (c) comprises placing a support member in the at least one aperture such that each end of the support member projects from the ceramic core by a predetermined distance.

Preferably step (b) comprises forming a plurality of apertures through the ceramic core and step (c) comprises placing a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

Preferably step (e) comprises supplying wax into the space between the die and the ceramic core.

Preferably the support member comprises platinum.

The present invention also provides a method of manufacturing a hollow component comprising the steps of:

(a) forming a ceramic core,

(b) forming at least one recess in the ceramic core,

(c) placing a support member in the recess such that at least one end of the support member projects from the ceramic core by a predetermined distance,

(d) placing the ceramic core and at least one support member in a die such that the ends of the support member locate the ceramic core in spaced relationship with the die to define the shape of the pattern of the hollow component,

(e) supplying molten disposable material into the space between the die and the ceramic core,

(f) allowing the disposable material to solidify to form a disposable pattern and

(g) removing the disposable pattern and ceramic core from the die,

(h) coating the disposable pattern with ceramic material to form a mould,

(i) heating the mould, disposable pattern and ceramic core to remove the disposable pattern from the mould,

(j) firing the mould to complete the ceramic shell mould,

(k) supplying molten material into the ceramic shell mould,

(l) solidifying the molten material in the ceramic shell mould to form a component,

(m) removing the ceramic shell mould from the component,

(n) removing the ceramic core from the component to form the hollow component.

Preferably step (b) comprises forming at least on aperture through the ceramic core and step (c) comprises placing a support member in the at least one aperture such that each end of the support member projects from the ceramic core by a predetermined distance.

Preferably step (b) comprises forming a plurality of apertures through the ceramic core and step (c) comprises

placing a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

Preferably step (e) comprises supplying wax into the space between the die and the ceramic core.

Preferably the support member comprises platinum.

Preferably step (k) comprises supplying molten metal, molten alloy or molten superalloy into the ceramic shell mould.

Preferably step (l) comprises directionally solidifying the molten material in the ceramic shell mould.

Preferably step (l) comprises forming a single crystal in the ceramic shell mould.

Preferably the hollow component is a turbine blade or a turbine vane.

The present invention also provides a ceramic core for a disposable pattern comprising at least one aperture extending therethrough, and a support member in the at least one aperture such that each end of the support member projects from the ceramic core by a predetermined distance.

Preferably the ceramic core comprises a plurality of apertures therethrough, and a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

Preferably the support member comprises platinum.

The present invention also provides a disposable pattern comprising at least one ceramic core, the at least one ceramic core comprising at least one aperture extending therethrough, and a support member in the at least one aperture such that each end of the support member projects from the ceramic core by a predetermined distance.

Preferably the disposable pattern comprises a plurality of ceramic cores, each ceramic core comprising at least one aperture extending therethrough, and a support member in the at least one aperture such that each end of the support

member projects from the ceramic core by a predetermined distance.

Preferably the ceramic core comprises a plurality of apertures therethrough, and a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

Preferably the support member comprises platinum.

Preferably the disposable pattern comprises wax.

The present invention will be more fully described by way of example with reference to the accompanying drawings in which:-

Figure 1 is a perspective view of a hollow turbine blade manufactured by the method according to the present invention.

Figure 2 is a perspective view of a ceramic core according to the present invention.

Figure 3 is a cross-sectional view through the ceramic core shown in figure 2.

Figure 4 is a cross-sectional view through a disposable pattern according to the present invention.

Figure 5 is a cross-sectional view through a ceramic shell mould containing the disposable pattern shown in figure 4.

Figure 6 is a cross-sectional view through the ceramic shell mould in figure 5 after the disposable pattern has been removed leaving the ceramic core, and

Figure 7 is a cross-sectional view through the turbine blade shown in figure 1.

Figure 8 is an alternative cross-sectional view through a disposable pattern according to the present invention.

A hollow component, or hollow article, for example a gas turbine engine turbine blade 10 is shown in figure 1. The turbine blade 10 comprises an aerofoil portion 12, a platform portion 14, a shank 16 and a root portion 18. The aerofoil portion 12 comprises one or more internal passages for the

flow of cooling fluid through the cooling passages so as to cool the turbine blade 10.

The turbine blade 10 is produced using the investment casting, or lost wax casting, process. Firstly one or more ceramic cores 20, as shown in figure 2 and 3, are produced to define the internal shape of the internal cooling passages for the turbine blade 10. One or more apertures 24 are formed all the way through each ceramic core 20 by drilling. Alternatively each ceramic core 20 may be cast, or moulded, with the apertures 24 all the way through the ceramic core 20. A support member 22, or support pin, is positioned within each of the apertures 24 such that each end 26A, 26B of the support member 22 extends a predetermined distance from the surface of the ceramic core 20. The predetermined distances depend upon the thickness of the aerofoil portion 14 of the hollow turbine blade 10 to be made. The predetermined distances are equivalent to, or slightly less than, the thickness of the aerofoil portion 14 of the hollow turbine blade 10.

The ceramic core 20, or ceramic cores 20, together with its associated support members 22 is located in a pattern die, not shown. The pattern die defines the external shape of the turbine blade 10. The support members 22 are thus very close to, or abutting, the internal surface of the pattern die. The support members 22 locate the ceramic core 20 in the correct spaced relationship with the pattern die.

A disposable material 30, for example wax, is injected into the space between the pattern die and the ceramic core 20 to form a disposable pattern 28. The disposable pattern 28 encloses the ceramic core 20 and the support members 22. Once the disposable material has solidified the disposable pattern 28 and enclosed ceramic core 20 is removed from the pattern die, as shown in figure 4. This arrangement produces a single cooling passage in the aerofoil portion 14 of the turbine blade 10.

The disposable pattern 28 is dipped repeatedly in a ceramic slurry and granules of refractory material are sprinkled on the ceramic slurry to build up a suitable number of ceramic layers 34 to form a ceramic shell mould 32, as shown in figure 5. The support members 22 are not fixed in the ceramic shell mould 32, but they are very close to, or abut, the ceramic shell mould 32 and minimise relative movement of the ceramic shell mould 32 and ceramic core 20.

The ceramic shell mould 32 is heated to melt the disposable pattern 28 and leave the ceramic core 20 located accurately within the ceramic shell mould 32 by the support members 22, as shown in figure 6. The ceramic shell mould 32 is fired to remove the remaining traces of the disposable pattern 28 and to cure the ceramic shell mould 32.

The ceramic shell mould 32 is placed in a furnace and molten metal, for example a metal, alloy or superalloy or intermetallic is poured into the ceramic shell mould 32. The turbine blade 10 is formed by pouring a nickel base, or cobalt, superalloy or a nickel, or titanium, intermetallic into the ceramic shell mould 32. The molten metal is solidified to form the turbine blade 10. The solidification may be by conventional cooling to form an equiaxed structure in the turbine blade 10, by directional solidification to form a number of crystals extending from the root portion 18 to the aerofoil portion 14 of the turbine blade 10 or by using a single crystal selector, or a seed crystal, and directional solidification to form a single crystal turbine blade 10.

The ceramic shell mould 32 is removed to leave the turbine blade 10 containing the ceramic core 20 and support members 22. The ceramic core 20 is leached out of the turbine blade 10 to define the internal cooling passages in the turbine blade 10 and to leave the support members 22 in the turbine blade 10.

The advantages of the present invention are that the support members 22 extend across the internal cooling

passages of the turbine blade 10. The support members 22 increase the turbulence in the cooling fluid flow through the cooling passages in the aerofoil portion 14 of the turbine blade 10 and hence increase the cooling efficiency of the turbine blade 10. The support members 22 are not fixed in the ceramic shell mould 32 and hence the support members 22 will not produce stress in the solidifying metal to provide points for undesirable recrystallisation. The support members 22 do not project from the external surface of the turbine blade 10 and thus it is not necessary to dress of the ends of the support members 22 so that they are flush with the surface of the turbine blade 10, thus reducing costs and time.

An alternative disposable pattern 28A is injected into the space between the pattern die and two ceramic cores 20A and 20B. The disposable pattern 28A encloses the ceramic cores 20A and 20B and the support members 22A. Once the disposable material has solidified the disposable pattern 28A and enclosed ceramic cores 20A and 20B are removed from the pattern die, as shown in figure 8. This arrangement produces two cooling passages in the aerofoil portion 14 of the turbine blade 10. The use of more ceramic cores 20 will produce more cooling passages in the aerofoil portion 14 of the turbine blade 10. It may be possible for the ceramic cores 20 to be interconnected so that they from a series of cooling passages in which the cooling air flow is reverses in alternate cooling passages.

The support members 22 may be made of platinum, palladium, rhodium, rhenium, ceramic, or any suitable material which does not melt during the removal of the disposable pattern 28. The disposable pattern material may be wax or other suitable material. The ceramic shell mould 32 may be formed on the disposable pattern 28 by other suitable methods for example injection of a ceramic into a die enclosing the disposable pattern 28.

The support members have at most abutting point contact with the internal surface of the ceramic shell mould to minimise contact area between the support member and the ceramic shell mould. If the area of contact is too great, undesirable grain growth may be initiated at the abutting contact area and this may disrupt the desired grain growth.

The portion of the support members extending from the apertures have minimum, or small, volumes and surface areas. If the volumes and areas of the portions of the support members extending from the apertures are large, undesirable grain growth may be initiated from the support members. Additionally the portions of the support members have minimum volume to minimise the cost of material, particularly if the material is expensive e.g. platinum. Additionally the support members have simple shapes to minimise manufacturing costs e.g. cylindrical pins.

Claims:-

1. A method of manufacturing a disposable pattern of a hollow component comprising the steps of:

(a) forming a ceramic core,

(b) forming at least one recess in the ceramic core,

(c) placing a support member in the recess such that at least one end of the support member projects from the ceramic core by a predetermined distance,

(d) placing the ceramic core and at least one support member in a die such that the ends of the support member locate the ceramic core in spaced relationship with the die to define the shape of the pattern of the hollow component,

(e) supplying molten disposable material into the space between the die and the ceramic core,

(f) allowing the disposable material to solidify to form a disposable pattern and

(g) removing the disposable pattern and ceramic core from the die.

2. A method as claimed in claim 1 wherein step (b) comprises forming a plurality of apertures through the ceramic core and step (c) comprises placing a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

3. A method as claims in claim 2 wherein step (b) comprises forming a plurality of apertures through the ceramic core and step (c) comprises placing a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

4. A method as claimed in claim 1, claim 2 or claim 3 wherein step (e) comprises supplying wax into the space between the die and the ceramic core.

5. A method as claimed in any of claims 1 to 4 wherein the support member comprises platinum.

6. A method as claimed in any of claims 1 to 5 wherein the portion of the support member projecting from the recess has

a small volume to minimise undesirable grain growth on the support member.

7. A method as claimed in claim 6 wherein the support member is a pin.

8. A method of making a disposable pattern substantially as hereinbefore described with reference to figures of the accompanying drawings.

9. A method of manufacturing a ceramic shell mould comprising the steps of:

(a) forming a ceramic core,

(b) forming at least one recess in the ceramic core,

(c) placing a support member in the recess such that at least one end of the support member projects from the ceramic core by a predetermined distance,

(d) placing the ceramic core and at least one support member in a die such that the ends of the support member locate the ceramic core in spaced relationship with the die to define the shape of the pattern of the hollow component,

(e) supplying molten disposable material into the space between the die and the ceramic core,

(f) allowing the disposable material to solidify to form a disposable pattern and

(g) removing the disposable pattern and ceramic core from the die,

(h) coating the disposable pattern with ceramic material to form a mould,

(i) heating the mould, disposable pattern and ceramic core to remove the disposable pattern from the mould, and

(j) firing the mould to complete the ceramic shell mould.

10. A method as claimed in claim 9 wherein step (b) comprises forming a plurality of apertures through the ceramic core and step (c) comprises placing a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

11. A method as claimed in claim 10 wherein step (b) comprises forming a plurality of apertures through the ceramic core and step (c) comprises placing a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

12. A method as claimed in claim 9, claim 10 or claim 11 wherein step (e) comprises supplying wax into the space between the die and the ceramic core.

13. A method as claimed in any of claims 9 to 12 wherein the support member comprises platinum.

14. A method as claimed in any of claims 9 to 13 wherein the portion of the support member projecting from the recess has a small volume to minimise undesirable grain growth on the support member.

15. A method as claimed in claim 14 wherein the support member is a pin.

16. A method of manufacturing a ceramic shell mould substantially as hereinbefore described with reference to figures of the accompanying drawings.

17. A method of manufacturing a hollow component comprising the steps of:

(a) forming a ceramic core,

(b) forming at least one recess in the ceramic core,

(c) placing a support member in the recess such that at least one end of the support member projects from the ceramic core by a predetermined distance,

(d) placing the ceramic core and at least one support member in a die such that the ends of the support member locate the ceramic core in spaced relationship with the die to define the shape of the pattern of the hollow component,

(e) supplying molten disposable material into the space between the die and the ceramic core,

(f) allowing the disposable material to solidify to form a disposable pattern and

(g) removing the disposable pattern and ceramic core from the die,

(h) coating the disposable pattern with ceramic material to form a mould,

(i) heating the mould, disposable pattern and ceramic core to remove the disposable pattern from the mould,

(j) firing the mould to complete the ceramic shell mould,

(k) supplying molten material into the ceramic shell mould,

(l) solidifying the molten material in the ceramic shell mould to form a component,

(m) removing the ceramic shell mould from the component,

(n) removing the ceramic core from the component to form the hollow component.

18. A method as claimed in claim 17 wherein step (b) comprises forming a plurality of apertures through the ceramic core and step (c) comprises placing a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

19. A method as claimed in claim 18 wherein step (b) comprises forming a plurality of apertures through the ceramic core and step (c) comprises placing a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

20. A method as claimed in claim 17, claim 18 or claim 19 wherein step (e) comprises supplying wax into the space between the die and the ceramic core.

21. A method as claimed in any of claims 17 to 20 wherein the support member comprises platinum.

22. A method as claimed in any of claims 17 to 21 wherein step (k) comprises supplying molten metal, molten alloy or molten superalloy into the ceramic shell mould.

23. A method as claimed in any of claims 17 to 22 wherein step (l) comprises directionally solidifying the molten material in the ceramic shell mould.

24. A method as claimed in claim 23 wherein step (1) comprises forming a single crystal in the ceramic shell mould.

25. A method as claimed in any of claims 17 to 24 wherein the hollow component is a turbine blade or a turbine vane.

26. A method as claimed in any of claims 17 to 25 wherein the portion of the support member projecting from the recess has a small volume to minimise undesirable grain growth on the support member.

27. A method as claimed in claim 26 wherein the support member is a pin.

28. A method of manufacturing a hollow component substantially as hereinbefore described with reference to figures of the accompanying drawings.

29. A ceramic core for a disposable pattern comprising at least one recess, and a support member in the at least one recess such that at least one end of the support member projects from the ceramic core by a predetermined distance.

30. A ceramic core as claimed in claim 29 wherein the ceramic core comprises at least one aperture extending therethrough, and a support member in the aperture such that each end of the support member projects from the ceramic core by a predetermined distance.

31. A ceramic core as claimed in claim 30 wherein the ceramic core comprises a plurality of apertures therethrough, and a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

32. A ceramic core as claimed in claim 29, claim 30 or claim 31 wherein the support member comprises platinum.

33. A ceramic core as claimed in any of claims 29 to 32 wherein the portion of the support member projecting from the recess has a small volume to minimise undesirable grain growth on the support member.

34. A ceramic core as claimed in claim 33 wherein the support member is a pin.

35. A ceramic core substantially as hereinbefore described with reference to and as shown in figures of the accompanying drawings.

36. A disposable pattern comprising at least one ceramic core, the at least one ceramic core comprising at least one recess, and a support member in the at least one recess such that at least one end of the support member projects from the ceramic core by a predetermined distance.

37. A disposable pattern as claimed in claim 36 wherein the ceramic core comprises at least one aperture extending therethrough, and a support member in the aperture such that each end of the support member projects from the ceramic core by a predetermined distance.

38. A disposable pattern as claimed in claim 37 wherein the disposable pattern comprises a plurality of ceramic cores, each ceramic core comprising at least one aperture extending therethrough, and a support member in the at least one aperture such that each end of the support member projects from the ceramic core by a predetermined distance.

39. A disposable pattern as claimed in claim 37 or claim 38 wherein each ceramic core comprises a plurality of apertures therethrough, and a support member in each aperture such that each end of each support member projects from the ceramic core by a predetermined distance.

40. A disposable pattern as claimed in any of claims 36 to 39 wherein the support member comprises platinum.

41. A disposable pattern as claimed in any of claims 36 to 40 wherein the disposable pattern comprises wax.

42. A disposable pattern as claimed in any of claims 36 to 41 wherein the portion of the support member projecting from the recess has a small volume to minimise undesirable grain growth on the support member.

43. A disposable pattern as claimed in claim 42 wherein the support member is a pin.

44. A disposable pattern substantially as hereinbefore described with reference to and as shown in figures of the accompanying drawings.

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19

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Application No: GB 9902285.7 **Examiner:** Monty Siddique
Claims searched: 1-28 **Date of search:** 28 April 1999

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2150875 A	(ROLLS-ROYCE) entire document and particularly tie member 14 which may be regarded as a support member	1, 9, 17 at least
A	GB 1219527	(T.R.W.)	
A	US 4986333	(ROLLS-ROYCE)	
A	US 4596281	(TRW)	
A	US 3957104	(NASA)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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